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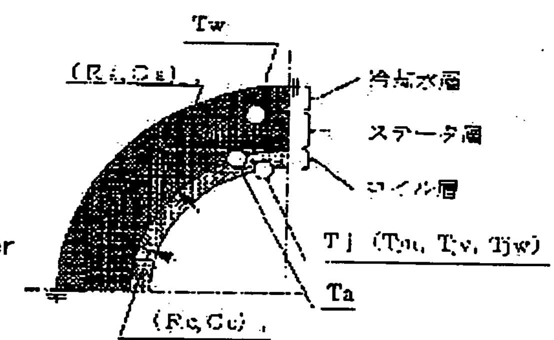
(54) SYNCHRONOUS MOTOR AND MOTOR VEHICLE COMPRISING IT AND ITS CONTROLLING METHOD

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a synchronous motor in which abnormal temperature rise is suppressed by predicting the temperature at a most overheated part of a winding through temperature measurement at one point, an electric vehicle comprising the synchronous motor and its controlling method.
SOLUTION: The synchronous motor comprises a current sensor for detecting the AC current of two or more phases out of three-phase AC currents of the synchronous motor, a temperature sensor for detecting the temperature of the synchronous motor, and a temperature protective means for suppressing temperature rise of the synchronous motor wherein the temperature sensor comprises an operating unit for predicting the temperature of other windings based on the detected temperature located at a position for detecting the temperature of one of the windings for supplying the three-phase AC currents.

図2



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CLAIMS

[Claim(s)]
[Claim 1] In the synchronous motor equipped with the current sensor which detects the alternating current of two or more phases of the three-phase-circuit alternating current of a synchronous motor, the temperature sensc which detects the temperature of said synchronous motor, and the temperature protective device which controls the temperature rise of said synchronous motor Said temperature sensor is formed in the location which detects the temperature of one coil in the coil which supplies the alternating current of said three phase circuit. It is the synchronous motor which has the arithmetic unit which predicts the temperature of other coils based on said detected temperature, and is characterized by said temperature protective device being what controls said temperature rise by computing and outputting the torque command to said synchronous motor based on said predicted temperature.
[Claim 2] The synchronous motor which the attachment location of said temperature sensor is the maximum hc spot of said coil, and is characterized by computing the temperature detected by said temperature sensor, and the temperature of the coil which has not attached said temperature sensor based on the current value detected by said current sensor with said arithmetic unit in claim 1.
[Claim 3] It is the synchronous motor characterized by computing the temperature which said temperature sensor was formed in one of said the coils in claim 1, and was detected by said temperature sensor, and the temperature of the maximum hot spot of the coil which has not attached said temperature sensor based on the current value detected by said current sensor with said arithmetic unit.
[Claim 4] It is the electric rolling stock characterized by said synchronous motor consisting of either of claims 1-3 in the electric rolling stock equipped with supply receptacle ************ of power through the power converter from the dc-battery.
[Claim 5] While detecting the alternating current of two or more phases of the three-phase-circuit alternating current of a synchronous motor In the control approach of the synchronous motor which detects the temperatur of the coil which supplies the three-phase-circuit alternating current of said synchronous motor, and controls th temperature rise of said synchronous motor based on the this detected temperature Said temperature to detect is what detects the temperature of one coil in the coil which supplies the alternating current of said three phase circuit. The control approach of the synchronous motor which predicts the temperature of other coils based on said detected temperature, and is characterized by controlling the temperature rise of said synchronous motor based on the this predicted temperature.

[Translation done.]

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the electric rolling stock using a new synchronous motor and new it, and its control approach, and relates to the control unit and the control approach of driving the synchronous motor preferably carried in electric rolling stock.
[0002]
[Description of the Prior Art] The motor which has spread industrial use through a large field at first has many to which the temperature sensor is attached, and when temperature rises unusually, it is common to take the configuration which the amount of energization is restricted, or a condensator is operated, and avoids breakage of a device.
[0003]
[Problem(s) to be Solved by the Invention] Since calorific value differs greatly for every phase when it energizes below at a specific rotational frequency, a temperature gradient produces a synchronous motor in eac interphase of a coil. For this reason, when hanging temperature protection so that it may become below a predetermined value about coil temperature, it is necessary to attach a temperature sensor for every phase. However, there is a problem that attaching a temperature sensor for every phase and its location cannot necessarily be set as the maximum hot spot of a coil from constraint of workability, either.
[0004] The purpose of this invention predicts the temperature of the maximum hot spot of a coil by one thermometry, and is to offer the electric rolling stock using the synchronous motor and it which controlled the unusual temperature rise of a synchronous motor, and its control approach.
[0005]
[Means for Solving the Problem] In the synchronous motor with which this invention was equipped with the current sensor which detects the alternating current of two or more phases of the three-phase-circuit alternating current of a synchronous motor, the temperature sensor which detects the temperature of said synchronous motor, and the temperature safeguard which controls the temperature rise of said synchronous motor Said temperature sensor is formed in the location which detects the temperature of one coil in the coil which supplie the alternating current of said three phase circuit. It has the arithmetic unit which predicts the temperature of other coils based on said detected temperature, and is characterized by said temperature protective device being what controls said temperature rise by computing and outputting the torque command to said synchronous motor based on said predicted temperature.
[0006] The temperature which the attachment location of said temperature sensor is the maximum hot spot of said coil, and was detected by said temperature sensor, and the temperature of the coil which has not attached said temperature sensor based on the current value detected by said current sensor are computed with said arithmetic unit, Moreover, as for said temperature sensor, it is desirable to compute the temperature which was prepared in one of said the coils, and was detected by said temperature sensor, and the temperature of the maximum hot spot of the coil which has not attached said temperature sensor based on the current value detected by said current sensor with said arithmetic unit.
[0007] This invention is characterized by said synchronous motor consisting of either of the above-mentioned synchronous motors in the electric rolling stock equipped with supply receptacle ************ of power through the power converter from the dc-battery.
[0008] While this invention detects the alternating current of two or more phases of the three-phase-circuit

alternating current of a synchronous motor In the control approach of the synchronous motor which detects the temperature of the coil which supplies the three-phase-circuit alternating current of said synchronous motor, an controls the temperature rise of said synchronous motor based on the this detected temperature It is characterized by for said temperature to detect detecting the temperature of one coil in the coil which supplies the alternating current of said three phase circuit, predicting the temperature of other coils based on said detected temperature, and controlling the temperature rise of said synchronous motor based on the this predicte temperature.

[0009] That is, the temperature sensor to attach can be set to one by searching for the maximum hot spot temperature of the coil temperature of a V phase W phase by count based on specific relational expression whenever [motor alternating current detection values Iu, Iv, and Iw and motor actual temperature / value / Ts / detection]. Moreover, if correlation of the temperature of the sensing location of the maximum hot spot and temperature is known even if it does not attach a temperature sensor to the maximum hot spot of a coil, the fitting location of a temperature sensor can be made into the easy location of an activity, and high productivity will be acquired.

[0010]

[Embodiment of the Invention] Drawing 1 is the block diagram of the drive control system for electric rolling stock which applied the synchronous motor equipped with the control unit of this invention. A synchronous motor 1 is a permanent-magnet type synchronous motor, uses a dc-battery 7 as a power source, carries out an inverter, i.e., an inverter, for a power converter 2, and receives supply of power. The capacitor 5 which carries out smooth [of the input voltage] to the direct-current input side of a power converter 2, and the direct-current input voltage sensor 6 which measures the direct-current input voltage to a power converter 2 are connected to the permanent-magnet type synchronous motor 1, and a direct-current input voltage value is transmitted to a control unit 8. Moreover, the current sensor 9 which measures the alternating current of a synchronous motor 1 to the alternating current power output side of a power converter 2 is installed in U phase, V phase, and W phase, respectively, and transmits the alternating current value of each phase to motor temperature presumption equipment 11. Moreover, the motor temperature sensor 4 is attached to the permanent-magnet type synchronou motor 1 at U phase of a coil, and the signal of the motor temperature sensor 4 is inputted into motor temperatur presumption equipment 11. Since a control unit 8 obtains the torque command Tref1 from the temperature protective device 10 and outputs the torque as the torque command Tref, it controls delivery and a power converter 2 for a 6 phase PWM signal to a power converter 2. In the temperature protective device 10, the criteria torque command Tref is received from the circuit which is not illustrated, and the torque command Tref1 which controls a motor temperature rise based on the motor temperature maximum which motor temperature presumption equipment 11 outputs is computed and outputted.

[0011] Drawing 2 is drawing showing the temperature model of motor winding. R and C express thermal resistance and heat capacity, respectively, W expresses calorific value and Tw expresses a circulating water temperature. A suffix "a" and "c" are attached to distinction of a stator layer and a coil layer. For simplification a cooling water layer presupposes that the temperature distribution by the existence of passage are nothing, and the temperature distribution of cooling water are made into homogeneity. A heat source is considered only as the loss of a coil and receipts and payments of the heat of the engine system transmitted through iron loss, a shaft, etc. are disregarded. Moreover, a coil is treated as a mass. Since heat capacity is very small, the slot liner between a coil layer and a stator layer usually disregards a time constant, and a resisted part is included in one of a coil layer and the stator layers, and is treated. Suppose that a temperature sensor is attached to the maximum hot spot of U phase winding.

[0012] Especially in a low-speed rotation region, generation of heat by energization is a main thing, and the temperature rise of the coil section of this motor is the calorific value of a UVW phase. Calorific value Wu=r-Iu2 Wu=r-Iv2 Wu=r-Iw2 Formula (1)

Calorific value of a Wx:UVW phase winding, r: It can formulize in the amount of energization of a wirewound resistor and an Ix:UVW phase winding. If the coil temperature Tu, Tv, and Tw of each UVW phase is developed to a mathematical theory according to the physical model of drawing 2 , it will be expressed by following formula (2) - (5).

[0013]

[Equation 1]

$$Tu = (Wu \times 3Rc + Ta) \times \frac{1}{1+\tau a \cdot s} \quad 式(2)$$

[0014]
[Equation 2]

$$Tv = (Wv \times 3Rc + Ta) \times \frac{1}{1+\tau a \cdot s} \quad 式(3)$$

[0015]
[Equation 3]

$$Tw = (Ww \times 3Rc + Ta) \times \frac{1}{1+\tau a \cdot s} \quad 式(4)$$

[0016]
[Equation 4]

$$Ta = (Wu+Wv+Ww) \times Rs + Tw) \times \frac{1}{1+\tau a \cdot s} \quad 式(5)$$

[0017] However, the heating value which flows into a stator is a mathematical solution. W= {(Wu+Wv+Ww) - Cc-Ta-s} /{1+tauc-s} Formula (6)
For simplification, it considers as the following formula (7) and carries out simple instead of ******.
W= (Wu+Wv+Ww) Formula (7)
[0018] Since [a temperature sensor] it is attached to U phase, U phase-winding temperature Tu can carry out direct observation. Moreover, by the ability finding the U phase current Iu from a current sensor, since a wirewound resistor r, thermal resistance Rc, and thermal time constant taua are known beforehand, it can be found by the amount of [by stator temperature / Tf] coil temperature change by the formula (8) which changed the formula (2).
[0019]
[Equation 5]

$$Tf = \frac{Ta}{1+\tau a \cdot s} = Tu - \frac{Wu \times 3Rc}{1+\tau a \cdot s} \quad 式(8)$$

[0020] Moreover, if based on a formula (1), (3), (4), and (8), VW phase-winding temperature Tv and Tw is also computable, since the VW phase current IvIw is searched for from a current sensor with count.
[0021] Here, the computer containing the program recorded on Memory ROM, CPU which reads this program and performs predetermined processing along with the procedure of a program, and the memory RAM which records said program, a function required for processing, a constant, data, etc. constitutes motor temperature presumption equipment 11.
[0022] Drawing 3 shows the processing flow of the program for motor temperature presumption equipments of drawing 1 with a flow chart. This CPU performs this program at a predetermined interval.
[0023] A program flow is step [in drawing] **, inputs Data Ts whenever [actual temperature / which a temperature sensor outputs], and inputs the alternating current sensor outputs Iu, Iv, and Iw further. Next, the magnitude of a rotational frequency is judged, and by step ** in drawing, when the magnitude of a rotational frequency is below a predetermined value (YES in drawing), below step ** is performed below, and when the magnitude of a rotational frequency is larger than a predetermined value (NO in drawing), the step in drawing (10) is performed. In step **, the calorific value Wu, Wv, and Ww of each coil is computed based on the above mentioned formula (1) using the alternating current sensor outputs Iu, Iv, and Iw. Next, Ts is converted into the

maximum hot spot temperature of U phase winding in step **. For example, when the difference of the maximum hot spot temperature Tu of Data Ts and U phase winding is proportional to the square of the amount of energization whenever [actual temperature], it is Tu = Ts+K-Iu2. What is necessary is just to amend. Next, in step **, it asks for a part for the stator temperature effect Tf by the formula (8). Next, by step **, Tv is calculated by the formula (3) based on Iv and Tf. Next, by step **, Tw is calculated by the formula (4) based oı Iv and Tf. By step **, the inner maximum temperature of Tu, Tv, and Tw is chosen, and it outputs to the buffer Buf arranged on memory. On the other hand, at a step (10), while stopping temperature forecasting calculation and outputting Data Ts to the above-mentioned buffer Buf as it is whenever [actual temperature], the filter variable used by step ** - ** is initialized. In step **, change per time amount is restricted to the appearance which is not changed rapidly [the maximum temperature].

[0024] Drawing 4 is the circuit diagram showing the time response amendment approach of a temperature sensor output. So far, although the temperature sensor attachment location was made into the maximum hot spc of U phase winding, when it cannot attach to the maximum hot spot due to an activity, it may attach to another location, it may amend like a formula (9), and Tu may be converted. Moreover, when the response of a temperature sensor is slower than the time constant of the temperature of a motor, whenever [actual temperature] is amended by the tracking loop formation shown in drawing 4 . As one example, the response oi a temperature sensor was made into primary delay by drawing 4 .

Tu=f (temperature-sensor detection value), f(): Correction function of a temperature sensor Formula (9)

[0025] Therefore, although the above example considered the motor temperature sensor as U phase attachment, even if it attaches to either V phase and W phase, it is clear that a function can be offered by the same count.

[0026]

[Effect of the Invention] It is not necessary to attach one temperature sensor to the coil three phase circuit of a motor respectively, and according to this invention, since a temperature sensor can be set to one, actuation can be done easily. Moreover, even if the speed of response of a temperature sensor is not necessarily early, since you may not be the maximum hot spot, the workability in motor manufacture is high [it is highly precise, and / since the temperature data of a desired motor can be obtained, the attachment location of a temperature sensor i attached and is an easy location, and].

[Translation done.]

* NOTICES *

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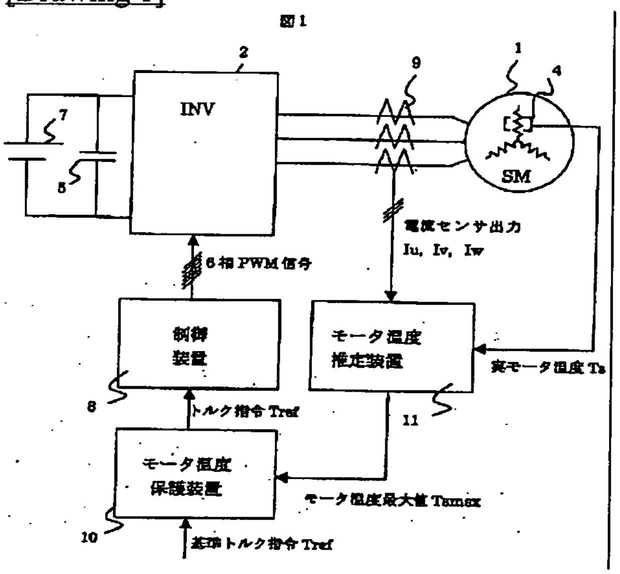
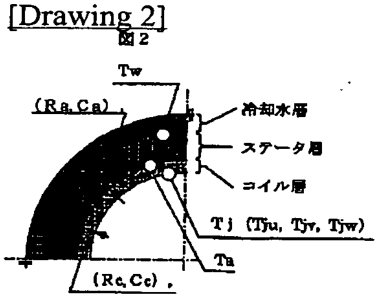
3.In the drawings, any words are not translated.

DRAWINGS

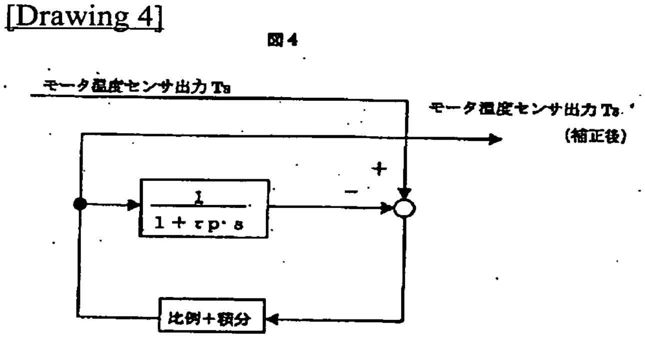
[Drawing 1]



[Drawing 2]

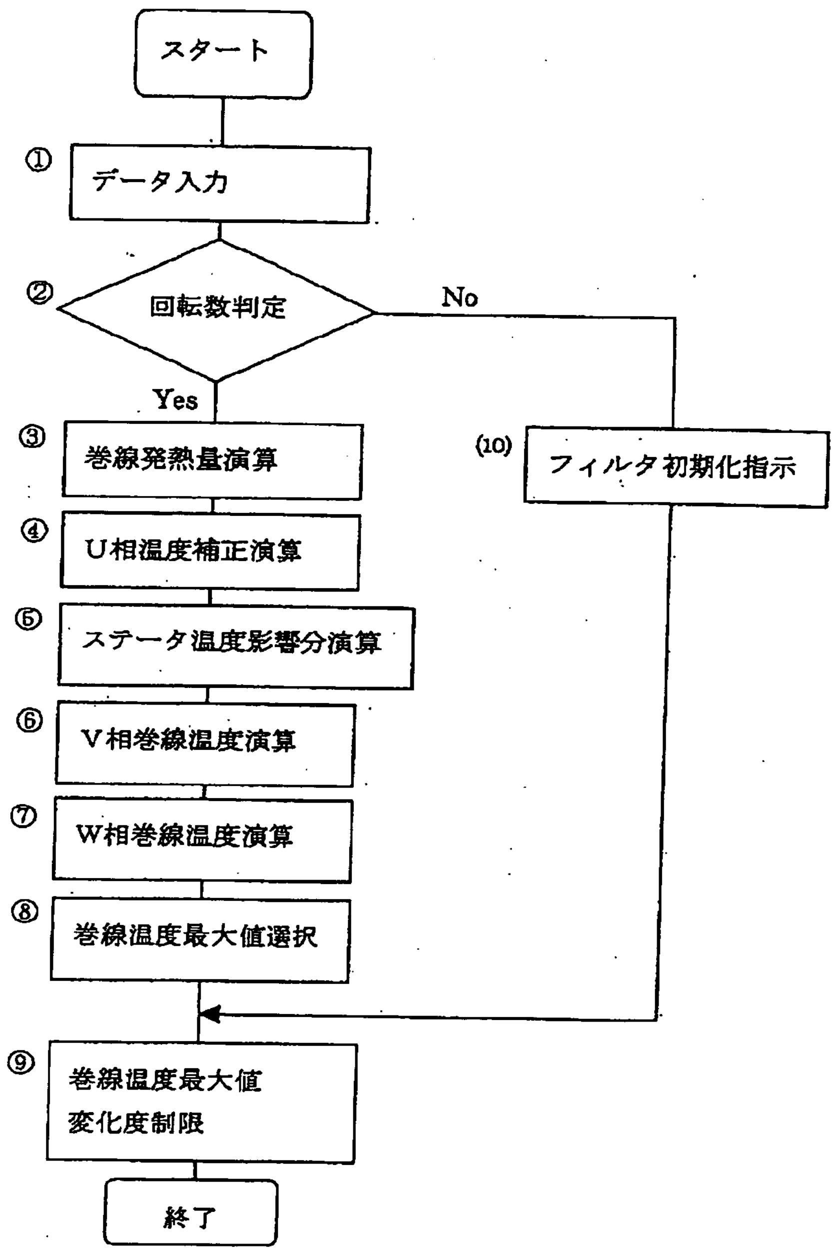


[Drawing 4]



[Drawing 3]

図 3



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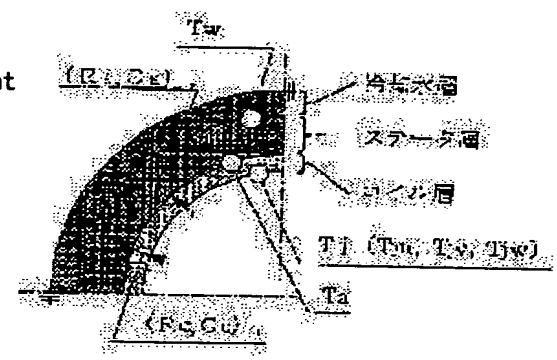
PROBLEM TO BE SOLVED: To provide a synchronous motor in which abnormal temperature rise is suppressed by predicting the temperature at a most overheated part of a winding through temperature measurement at one point, an electric vehicle comprising the synchronous motor and its controlling method.

SOLUTION: The synchronous motor comprises a current sensor for detecting the AC current of two or more phases out of three-phase AC currents of the synchronous motor, a temperature sensor for detecting the temperature of the synchronous motor, and a temperature protective means for suppressing temperature rise of the synchronous motor wherein the temperature sensor comprises an operating unit for predicting the temperature of other windings based on the detected temperature located at a position for detecting the temperature of one of the windings for supplying the three-phase AC currents.

図2



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Ｂ６０Ｌ　3/00		Ｂ６０Ｌ　3/00	Ｈ	５Ｈ５７６
Ｈ０２Ｋ　11/00		Ｈ０２Ｋ　11/00	Ｅ	５Ｈ６１１

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最終頁に続く

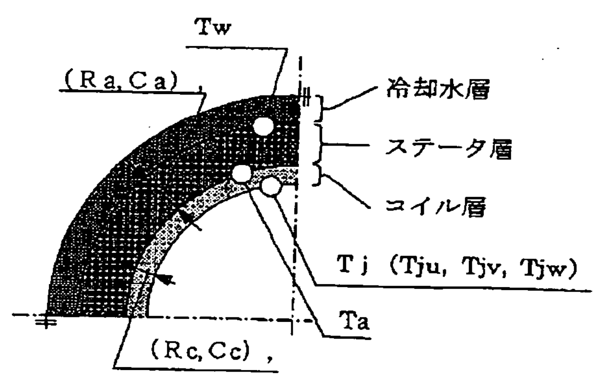
(54)【発明の名称】　同期電動機とそれを用いた電気車及びその制御方法

(57)【要約】

【課題】本発明の目的は、１個所の温度測定によって巻線の最過熱部の温度を予測し、同期電動機の異常な温度上昇を抑制した同期電動機とそれを用いた電気車及びその制御方法を提供するにある。

【解決手段】本発明は、同期電動機の３相交流電流の２相以上の交流電流を検出する電流センサと、前記同期電動機の温度を検出する温度センサと、前記同期電動機の温度上昇を抑制する温度保護手段とを備えた同期電動機において、前記温度センサは前記３相の交流電流を供給する巻線のうちの１つの巻線の温度を検出する位置に設けられ、前記検出された温度に基づいて他の巻線の温度を予測する演算装置を有することを特徴とする。

図２



【特許請求の範囲】

【請求項１】同期電動機の３相交流電流の２相以上の交流電流を検出する電流センサと、前記同期電動機の温度を検出する温度センサと、前記同期電動機の温度上昇を抑制する温度保護装置とを備えた同期電動機において、前記温度センサは前記３相の交流電流を供給する巻線のうちの１つの巻線の温度を検出する位置に設けられ、前記検出された温度に基づいて他の巻線の温度を予測する演算装置を有し、前記温度保護装置は前記予測された温度に基づいて前記同期電動機へのトルク指令を算出して出力することにより前記温度上昇を抑制するものであることを特徴とする同期電動機。

【請求項２】請求項１において、前記温度センサの付設位置が前記巻線の最過熱部であり、前記温度センサによって検出された温度と前記電流センサによって検出された電流値に基づいて前記温度センサを付設していない巻線の温度を前記演算装置にて算出することを特徴とする同期電動機。

【請求項３】請求項１において、前記温度センサは前記巻線の１つに設けられ、前記温度センサによって検出された温度と前記電流センサによって検出された電流値に基づいて前記温度センサを付設していない巻線の最過熱部の温度を前記演算装置にて算出することを特徴とする同期電動機。

【請求項４】バッテリから電力変換器を通して電力の供給受ける同期電動機を備えた電気車において、前記同期電動機は請求項１～３のいずれかから成ることを特徴とする電気車。

【請求項５】同期電動機の３相交流電流の２相以上の交流電流を検出すると共に、前記同期電動機の３相交流電流を供給する巻線の温度を検出し、該検出された温度に基づいて前記同期電動機の温度上昇を抑制する同期電動機の制御方法において、前記検出する温度は前記３相の交流電流を供給する巻線のうちの１つの巻線の温度を検出するものであり、前記検出された温度に基づいて他の巻線の温度を予測し、該予測された温度に基づいて前記同期電動機の温度上昇を抑制することを特徴とする同期電動機の制御方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、新規な同期電動機とそれを用いた電気車及びその制御方法に係り、好ましくは電気車に搭載される同期電動機を駆動する制御装置及び制御方法に関する。

【０００２】

【従来の技術】産業用を初め、広い分野に普及している電動機は温度センサが付設されているものが多く、温度が異常に上昇した際は、通電量を制限したり冷却器を動作させ、機器の破損を回避する構成をとるのが一般的である。

【０００３】

【発明が解決しようとする課題】同期電動機は、特定の回転数以下で通電すると各相毎に発熱量が大きく異なるため、巻線の各相間に温度差が生じる。このため、巻線温度を所定値以下となるように温度保護を掛ける場合、温度センサを各相毎に付設する必要がある。しかし、作業性の制約から温度センサを各相毎に付設すること、その位置も巻線の最過熱部に必ずしも設定できないという問題がある。

【０００４】本発明の目的は、１個所の温度測定によって巻線の最過熱部の温度を予測し、同期電動機の異常な温度上昇を抑制した同期電動機とそれを用いた電気車及びその制御方法を提供するにある。

【０００５】

【課題を解決するための手段】本発明は、同期電動機の３相交流電流の２相以上の交流電流を検出する電流センサと、前記同期電動機の温度を検出する温度センサと、前記同期電動機の温度上昇を抑制する温度保護手段とを備えた同期電動機において、前記温度センサは前記３相の交流電流を供給する巻線のうちの１つの巻線の温度を検出する位置に設けられ、前記検出された温度に基づいて他の巻線の温度を予測する演算装置を有し、前記温度保護装置は前記予測された温度に基づいて前記同期電動機へのトルク指令を算出して出力することにより前記温度上昇を抑制するものであることを特徴とする。

【０００６】前記温度センサの付設位置が前記巻線の最過熱部であり、前記温度センサによって検出された温度と前記電流センサによって検出された電流値に基づいて前記温度センサを付設していない巻線の温度を前記演算装置にて算出すること、又前記温度センサは前記巻線の１つに設けられ、前記温度センサによって検出された温度と前記電流センサによって検出された電流値に基づいて前記温度センサを付設していない巻線の最過熱部の温度を前記演算装置にて算出することが好ましい。

【０００７】本発明は、バッテリから電力変換器を通して電力の供給受ける同期電動機を備えた電気車において、前記同期電動機は前述の同期電動機のいずれかから成ることを特徴とする。

【０００８】本発明は、同期電動機の３相交流電流の２相以上の交流電流を検出すると共に、前記同期電動機の３相交流電流を供給する巻線の温度を検出し、該検出された温度に基づいて前記同期電動機の温度上昇を抑制する同期電動機の制御方法において、前記検出する温度は前記３相の交流電流を供給する巻線のうちの１つの巻線の温度を検出するものであり、前記検出された温度に基づいて他の巻線の温度を予測し、該予測された温度に基づいて前記同期電動機の温度上昇を抑制することを特徴とする。

【０００９】即ち、モータ交流電流検出値Iu, Iv, Iwとモータ実温度検出値Tsより、特定の関係式に基づいてV

相W相の巻線温度の最過熱部温度を計算により求めることにより、取り付ける温度センサを１つにすることができる。また、温度センサを巻線の最過熱部に付設しなくても、最過熱部と温度のセンシング位置の温度の相関が既知であれば、温度センサの取付け位置を作業の容易な位置にすることができ、高い生産性が得られる。

【００１０】

【発明の実施の形態】図１は、本発明の制御装置を備えた同期電動機を適用した電気車用駆動制御システムの構成図である。同期電動機１は永久磁石型同期電動機でありバッテリ７を電源とし、電力変換器２を逆変換器すなわちインバータをして電力の供給を受ける。永久磁石型同期電動機１には、電力変換器２の直流入力側には、入力電圧を平滑するコンデンサ５と、電力変換器２への直流入力電圧を測定する直流入力電圧センサ６が接続され、直流入力電圧値を制御装置８に伝達する。また、電力変換器２の交流電力出力側には、同期電動機１の交流電流を計測する電流センサ９がU相，V相，W相にそれぞれ設置され、各相の交流電流値をモータ温度推定装置１１に伝達する。また、永久磁石型同期電動機１にはモータ温度センサ４が巻線のU相に付設され、モータ温度センサ４の信号はモータ温度推定装置１１に入力する。制＊御装置８は、トルク指令Tref１を温度保護装置１０より得て、トルク指令Tref通りのトルクを出力するため、６相PWM信号を電力変換器２に送り、電力変換器２を制御する。温度保護装置１０では、図示されない回路より基準トルク指令Trefを受け、モータ温度推定装置１１の出力するモータ温度最大値に基づいてモータ温度上昇を抑制するトルク指令Tref1を算出して出力する。

【００１１】図２はモータ巻線の温度モデルを示す図である。R，Cはそれぞれ熱抵抗と熱容量を現し、Wは発熱量、Twは冷却水温度を現す。ステータ層とコイル層の区別には、添え字“a”，“c”を付ける。簡略化のため、冷却水層は流路の有無による温度分布は無しとし冷却水の温度分布は均一とする。熱源は巻線のロスのみとし、鉄損及びシャフト等を介して伝わるエンジン系の熱の出入りは無視する。また、コイルはマスとして扱う。コイル層とステータ層間のスロットライナは、通常、熱容量が極めて小さいので時定数を無視し、抵抗分はコイル層とステータ層のどちらかに含めて扱う。温度センサは、U相巻線の最過熱部に付設することとする。

【００１２】このモータの巻線部の温度上昇は、特に低速回転域において、通電による発熱が主たるもので、UVW相の発熱量は、

発熱量Wu＝ r・Iu²，　Wu＝ r・Iv²，　Wu＝ r・Iw²　　式（１）

Wx：UVW相巻線の発熱量，r：巻線抵抗，Ix：UVW相巻線の通電量

にて定式化できる。UVW相それぞれの巻線温度Tu，Tv，Twを図２の物理モデルに従い、数理モデルに展開する　※

※と、下記の式（２）～（５）にて表現される。

【００１３】

【数１】

$$Tu = (Wu \times 3Rc + Ta) \times \frac{1}{1 + \tau a \cdot s} \qquad 式(2)$$

【００１４】

★★【数２】

$$Tv = (Wv \times 3Rc + Ta) \times \frac{1}{1 + \tau a \cdot s} \qquad 式(3)$$

【００１５】

☆☆【数３】

$$Tw = (Ww \times 3Rc + Ta) \times \frac{1}{1 + \tau a \cdot s} \qquad 式(4)$$

【００１６】

◆◆【数４】

$$Ta = (Wu + Wv + Ww) \times Rs + Tw) \times \frac{1}{1 + \tau a \cdot s} \qquad 式(5)$$

【００１７】但し、ステータに流入する熱量は数理解

W＝｛（Wu＋Wv＋Ww）－Cc・Ta・s｝／｛１＋τc・s｝　　式（６）

を使う代わりに、簡略化のため、下記の式（７）とし、簡略する。

W＝（Wu＋Wv＋Ww）　　式（７）

【００１８】温度センサはU相に付設されているとしたのでU相巻線温度Tuは直接観測できる。また、U相電流Iuは電流センサから求まり巻線抵抗ｒと熱抵抗Rcと熱時定数τaは予め既知であることから、式（２）を変更した

式（８）により、ステータ温度による巻線温度変化分Ｔｆが求まる。

＊【００１９】

＊ 【数５】

$$Tf = \frac{Ta}{1+\tau a \cdot s} = Tu - \frac{Wu \times 3Rc}{1+\tau a \cdot s} \qquad 式(8)$$

【００２０】又、Ｗ相電流IvIwも電流センサから求められるため、式（１）（３）（４）（８）に基づけばＶＷ相巻線温度Tv，Twも計算により算出できる。

【００２１】ここで、モータ温度推定装置１１は、メモリＲＯＭに記録されたプログラムと、このプログラムを読み出しプログラムの手順に沿って所定の処理を実行するＣＰＵと、前記プログラムや、処理に必要な関数、定数、データ等を記録するメモリＲＡＭを含むコンピュータによって構成する。

【００２２】図3は、図１のモータ温度推定装置用プログラムの処理フローをフローチャートにより示したものである。このＣＰＵは所定のインターバルでこのプログラムを実行する。

【００２３】プログラムフローは、図中のステップ①で、温度センサの出力する実温度データTsを入力し、更に、交流電流センサ出力Iu,Iv,Iwを入力する。次に、図中のステップ②で、回転数の大きさを判定し、回転数の大きさが所定値以下の場合（図中のYES）、以下ステップ③以下を実行し、回転数の大きさが所定値より大きい場合（図中のNO）は図中のステップ(10)を実行する。ステップ③では、交流電流センサ出力Iu,Iv,Iwを使い前述の式（１）に基づき各巻線の発熱量Wu,Wv,Wwを算出す ※

※る。次にステップ④にて、TsをＵ相巻線の最過熱部温度に換算する。例えば、実温度データTsとＵ相巻線の最過熱部温度Tuの差が通電量の自乗に比例している場合、$Tu = Ts + K \cdot I u^2$ にて補正すればよい。次にステップ⑤では、式（８）により、ステータ温度影響分Tfを求める。次にステップ⑥で、IvとTfに基づき式（３）にてTvを求める。次にステップ⑦で、IvとTfに基づき式（４）にてTwを求める。ステップ⑧で、Tu，Tv，Twの内最大温度を選択し、メモリ上に配置したバッファBufに出力する。一方、ステップ(10)では、温度推定計算を停止し前述のバッファBufには実温度データTsをそのまま出力すると共に、ステップ④～⑦で使用するフィルタ変数の初期化を行う。ステップ⑨では、最大温度の急激に変化させない様に時間当たりの変化を制限する。

【００２４】図４は温度センサ出力の時間応答補正方法を示す回路図である。ここまでは、温度センサ付設位置をＵ相巻線の最過熱部としたが、作業の関係で最過熱部に付設できない場合、別の位置に付設し、式（９）の様に補正してTuを換算しても良い。また、温度センサの応答がモータの温度の時定数より遅いときには、図４に示すトラッキングループで実温度を補正する。１例として、図４では温度センサの応答は１次遅れとした。

Tu＝ｆ（温度センサ検出値），ｆ（ ）：温度センサの補正関数　式（９）

【００２５】従って、以上の実施例はモータ温度センサをＵ相付設としたが、Ｖ相及びＷ相のいずれかに付設しても同様の計算にて機能を提供できることは明らかである。

【００２６】

【発明の効果】本発明によれば、モータの巻線３相に各々１つの温度センサを付設する必要がなく、温度センサを１つとすることができるため操作が容易にできる。又、温度センサは必ずしも応答速度の早いものでなくても、高精度で所望のモータの温度データを得られるので、温度センサの付設位置は取り付け容易な位置で、又、最過熱部でなくても良いので、モータ製造における作業性が高い。

【図面の簡単な説明】

【図１】本発明の同期電動機制御装置を備えた電気車の駆動制御システム構成図。

【図２】モータ巻線の温度モデル。

【図３】図１のモータ温度推定装置の処理フロー図。

【図４】温度センサ出力の時間応答補正方法を示す回路図。

【符号の説明】

１…同期電動機、２…電力変換器、４…モータ温度センサ、５…平滑コンデンサ、７…バッテリ、８…電動機制御装置、９…交流電流センサ、１０…モータ温度保護装置、１１…モータ温度推定装置

【図１】

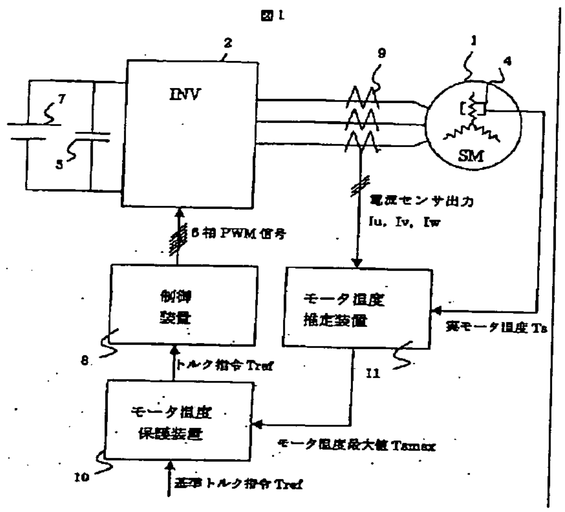


図1
INV
SM
2
9
1
4
7
5
6相 PWM 信号
電流センサ出力
Iu, Iv, Iw
制御
装置
モータ温度
推定装置
実モータ温度 Ts
8
11
トルク指令 Tref
モータ温度
保護装置
モータ温度最大値 Tsmax
10
基準トルク指令 Tref

【図２】

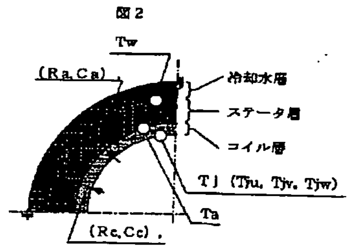


図2
Tw
(Ra,Ca)
冷却水層
ステータ層
コイル層
TJ (Tju, Tjv, Tjw)
Ta
(Rc,Cc)

【図４】

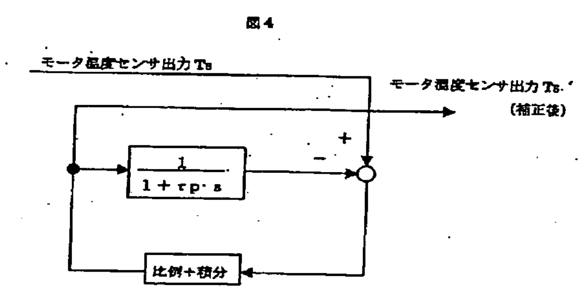
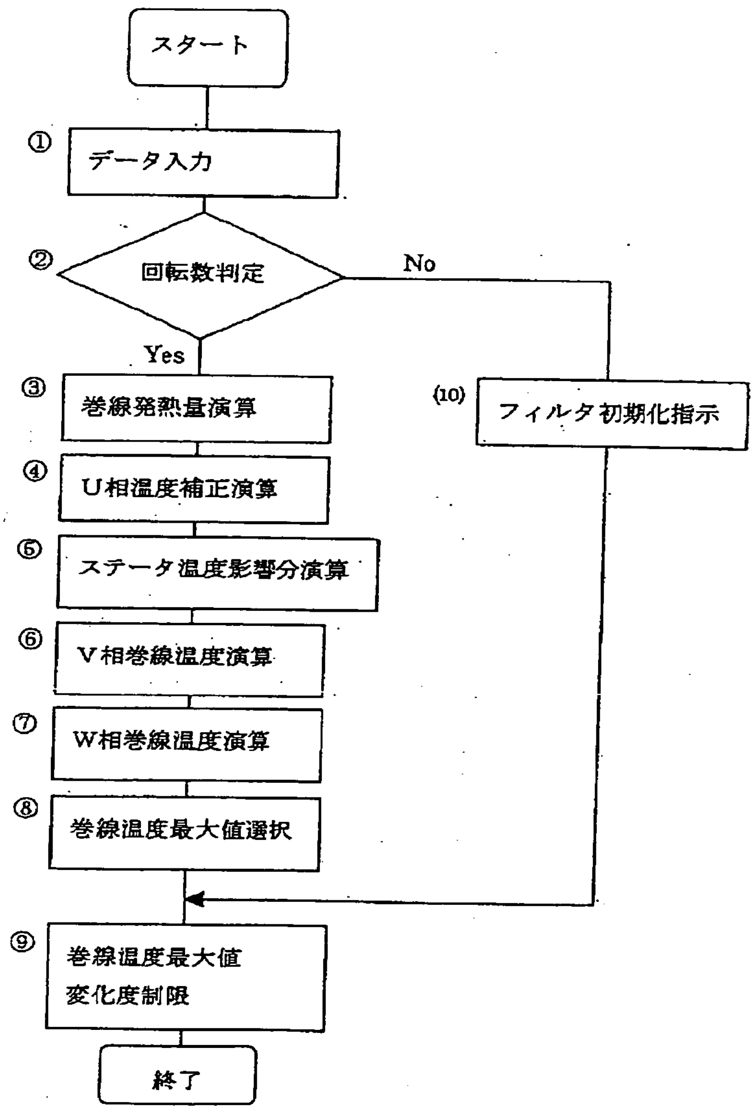


図4
モータ温度センサ出力 Ts
モータ温度センサ出力 Ts'
(補正後)
+
−
1
1＋τp・s
比例＋積分

【図３】

図３



フロントページの続き

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